**Ground Improvement**
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**Lecture 48**
**Soil Nailing (Contd.)**

Hi everyone, once again let us continue on this soil nailing topic this is the module, but now I will discuss different from soil nailing, already I have given a hint that there is similar type of application is their soil nailing and soil anchor, some soil anchor and little difference will be there and now for about different aspects including design I have discussed on soil nailing, now I will try to discuss while anchor what it is actually.

Generally, when we want to do sometime excavation, deep excavation and sometimes we can provide a seat pile wall and the seat pile wall sometimes is too deep then there will be too much of deflection and to prevent the deflection sometimes we can anchor, those are actual typical application of soil anchor, there are many other applications, will be there. That that anchor actually how it works, what is the applicability, what is the advantage, disadvantage, where it will suitable, where is not suitable, what material you can use it all those details and including design aspect we will discuss in one or two more lecture.

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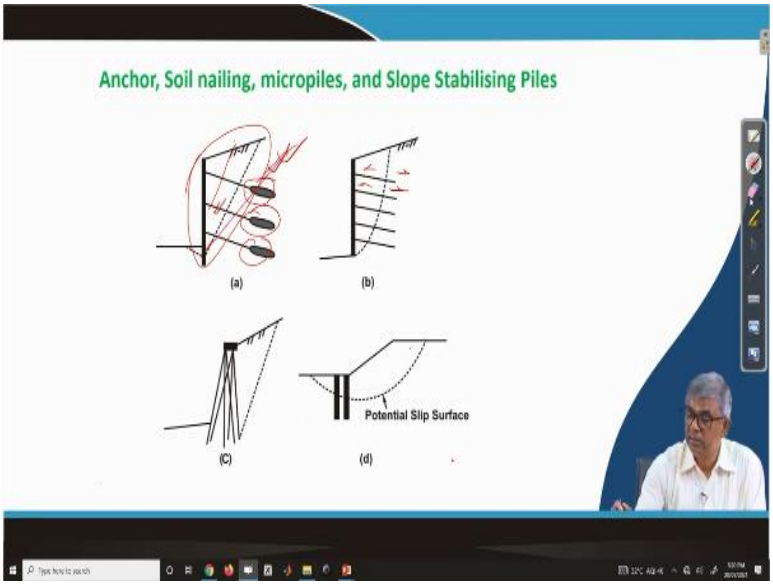

let us take the first slide that anchor, in the anchor before going to the anchor, let us show that similar things, different things which I will use, you can see here this is one, this is called soil anchor because you can see this is the active zone the soil will move along with wall and this is a resisting zone. Here main resistance will come from here, this is anchored they are sufficiently strong, you have to make strong so this anchor actually will be helping to stable this entire mass.

This is the anchor, the portion in the on the stabilize zone, on the resistance zone there will be portion when we strengthen more force will be transferred here, that is anchor. Whereas soil nail, the entire thing is the structural part, but in this direction, in this direction and this portion direction in this direction that is a difference. This is soil nail directly to be in use and these are some sort of batter pile to stabilize, you can see and this is actually some micropiles or some other materials to be used to or to prevent the slope.

Different ways actually, we can stabilize the slope that is what is shown in this example or in this figure here actually anchor here is a nail and there is a batter pile then these are some face piles actually you can say or micropile, generally rows of pile can be given here to prevent the movement of this march this direction. This is basic application, different methods, how we can stabilize and all method may not be discussed, we have discussed nail now we will discuss.

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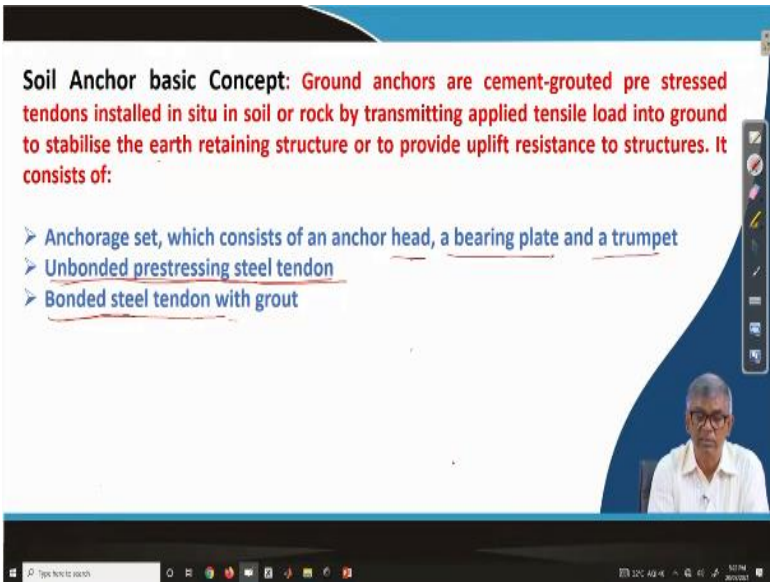


And soil anchor in the basic concepts like soil nail here what we do, actually here can see ground anchor cement or grouted a pre stressed tendons will be installed, cement grouted pre stressed tendons will be installed in situ soil or rock by transmitting applied tensile load into ground to stabilize the earth retaining structure or to provide uplift resistance, they are actually one example we are sure where it is falling and it is holding but there are some anchor will be there uplift will be helping the anchor will be to prevent uplift. I will show that sketch also so that different type of application will be there. It is here cement grouted pre stressed tendon, they are actually nail is not pre stressed it will simply be given and then routed and then when it will be pull this side it will have resistance develop on the surface but here it is pre stressed that is the difference in anchor and this one.

And then here what are the different things, there are a few components in it, there is the anchorage set which consists of an anchor head, then a bearing plate and a trumpet and there will be un bonded pre stressing steel tendon and there will be bonded, the un bonded pre stressing steel but that is what I have show and bonded steel tendon with grout, so there will be three components, three parts, which I will be showing again in enlarged view of that one.

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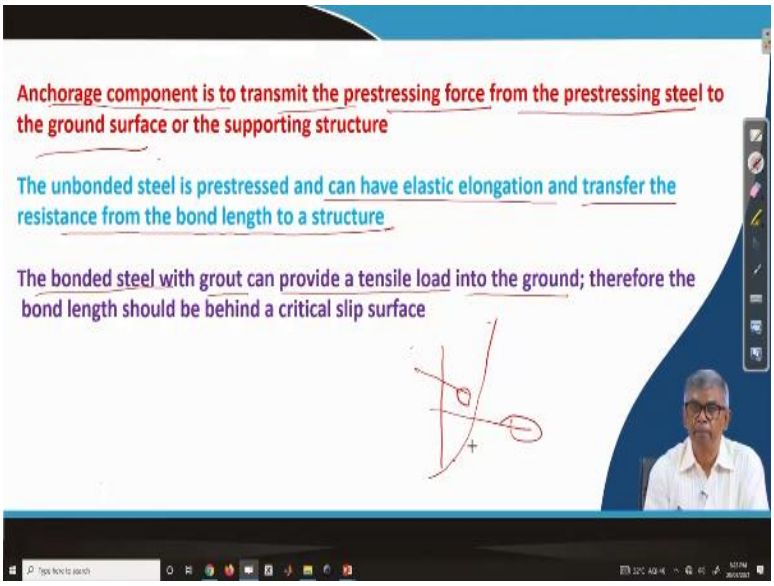


And then the anchor is component is to transmit the pre stressing force from the pre stressing steel to the ground surface. This is anchorage component; the function of the anchorage component is to transmit pre stressing force from the pre stressing steel to ground and the un bonded steel is pre stressed and can have elastic elongation and transfer the resistance from the bond length to the structure.

That is the function and bonded steel with grout can provide a tensile load into the ground that is the function. There are three parts will have three different functions. Therefore, the bond length should be behind the critical slip surface. That means if this is the wall and slip surface is this one and bond length this here it is not good, not at all useful, it should be here, that is what it is mentioned here.

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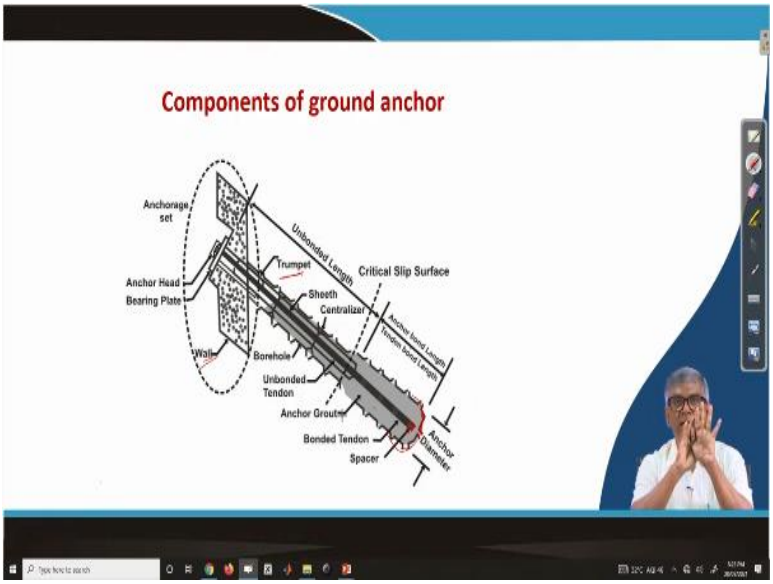


As I have told you that I will try to show you the more detail about this, you can see in this here that anchor is set, an anchor head is this one and then bearing plate is there and then you can see that this is actually bonded part, this is the bonded part, you can see anchor bond length, tendon bond length is mentioned, this is a bonded part and this is the un bonded part and this is the pillar surface.

Beyond that, it should be that is what it is mentioned and you can see there are a number of things that they are actually, borehole done like these up to these and then this is the grout is given and bonded and tendon is this and main the same, this is bonded with grout and this will be an anchor diameter, this is anchor diameter, totally anchor diameter this to this together is anchor this is not, this much is the anchor, anchor is together with this and there are trumpet and etc., this is the trumpet is given as it is mentioned before and this is wall and so different components of a particular anchor which will be there.

This is the wall and is connected and then what are the different parts, the failure surface may be here, the bonded length will be here like that, this is the different component by large shown in this figure.

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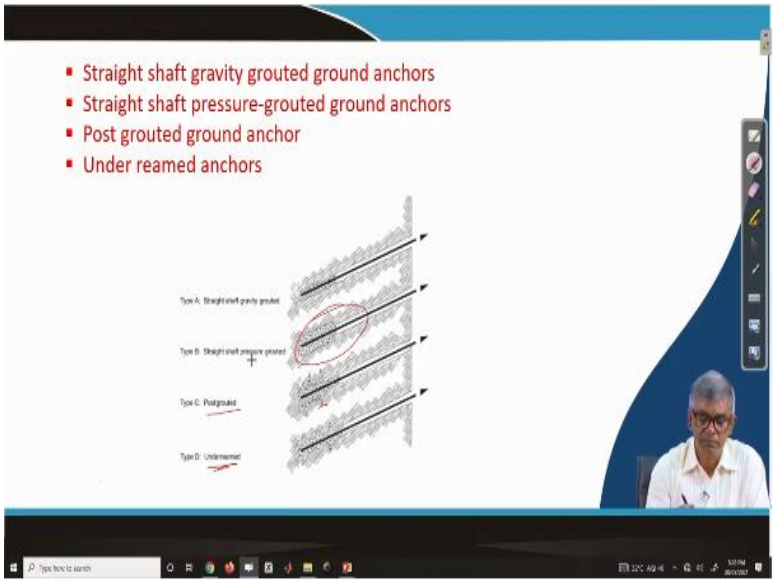


And there are, again anchor can be of different types, there are four types, type A, type B, type C, type D, straight shaft gravity grouted ground anchors. This is the one straight shaft gravity grouted and straight shaft pressure grouted, this is the one, then post grouted, this is the one and this is the under reamed. The different ways construction can be done so most common actually this one.

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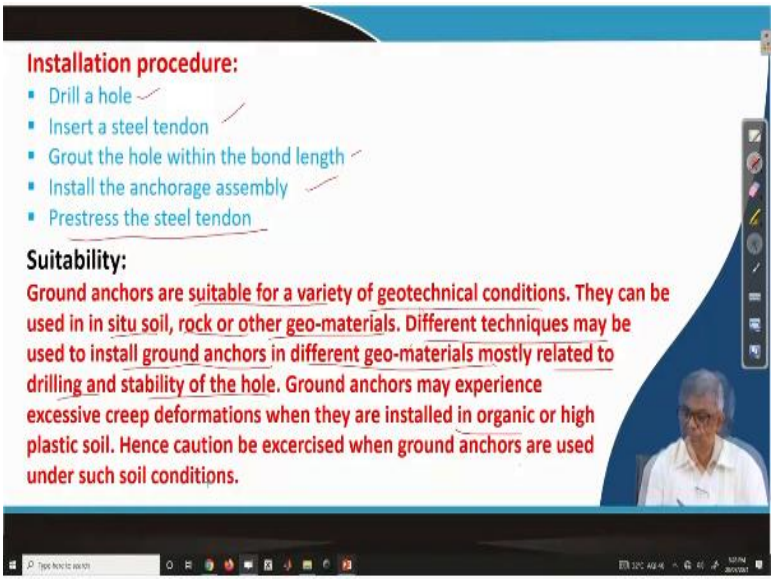

And installation procedure, you can see that first of all you had to make a drill hole and then installed a steel tendon, then grout the hole with the bond length, whatever that much portion to bonded, install the anchorage assembly and then pre stress the steel tendon, that is the steps in the construction.

And suitability ground anchors are suitable for a variety of geotechnical conditions, they can be used in situ soil, rock or other geo materials, different techniques may be used to install ground anchors in different geo materials mostly related to drilling and stability of the hole. The stability of the holes means when you make a borehole, then immediately borehole can collapse, to prevent that, different technique has to be used.

And different soil drilling cannot be so simple drilling one rock deep drilling is different, when it is a soil clay it will be different, then we silt it with different, clay is different, so like that. Ground anchors may experience excessive creep deformation when they are installed in organic or high plastic soil and because of that, they are not hence the caution be exercised when ground anchors are used under such soil condition.

Similar to the nail also we have mentioned that when is a plastic soil then there will be deformation that because of that they are actually and here actually in organic and high plastic soil that creep deformation sometime will release that prestressing load and because of that, the caution has to be taken for using this type of soil.

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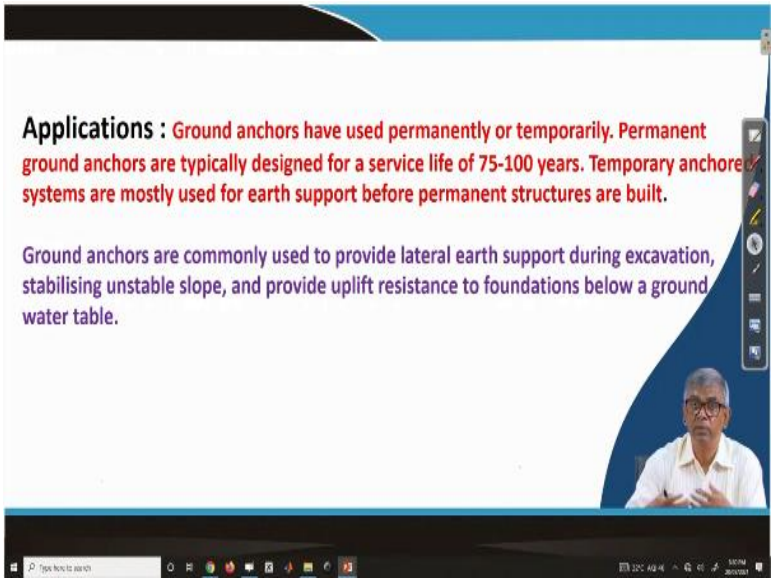


So again, in detail we will discuss the applications, ground anchors have used permanently or temporarily, both the temporary actually sometimes when there will construction that I have given example seat pile wall, that is after construction seat pile will be lifted so anchor will be lifted but sometime permanently also it can be done. Permanent ground anchors are typically designed for a service life of 75 to 100 years and temporary anchor systems are mostly used for each support before permanent structure will be built, so to prevent collapse actually till the construction is completed generally used.

And if it is a permanent it will be like a building or in the system or in a structure whatever life of the structure the anchor also, we have some structure, so it can be beyond 50 years so 75 to 100 it can be. And the ground anchors are commonly used to provide lateral earth support during excavation, stabilizing unstable slope and provide uplift resistance to foundation below grounds water table. That is actually uplift resistance below ground, if below the foundation there is a water there is uplift. To prevent that that shall be anchor, those things are there, different application of anchors.

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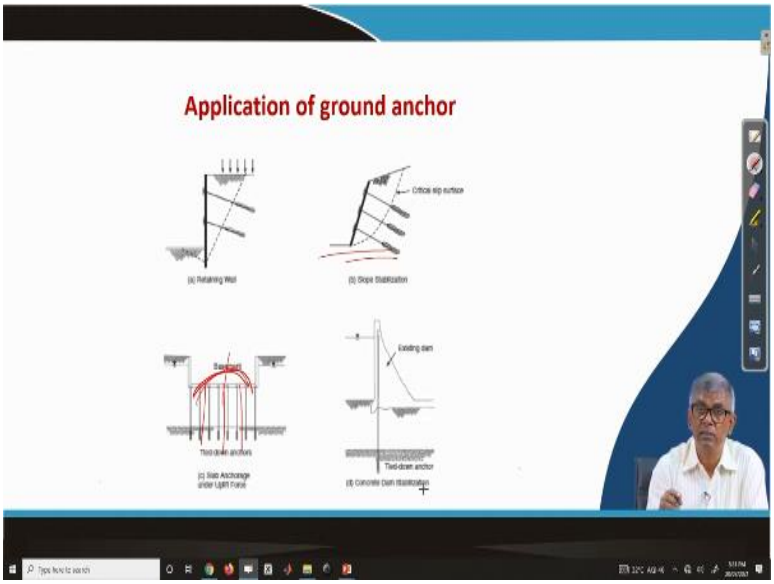


Let us see that there are some applications of anchors you can see in this picture or in this figure, you can see here the retaining wall can be anchored like this and this is slope stabilization, this can be anchored like this and then this is that the basement and there may be because of this pressure it maybe heaving like that. To prevent that there it can be anchored to the permanent strong ground and similarly this dam also it can be anchored to some strong base. These are all different areas of application of the anchors.

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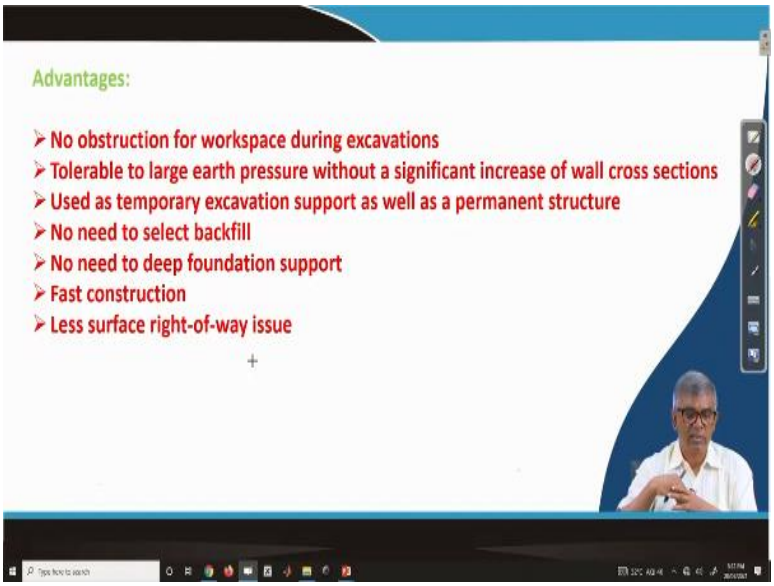


And then advantage there are some advantages will be there, when you use anchor actually no obstruction for workspace during excavation, no obstruction for workspace during excavation. If you use anchor, no obstruction will be there and tolerable to large earth pressure without a significant increase of wall cross section. If you use you can increase the pressure but without increasing the thickness of the wall, used as temporary excavation support as well as permanent structures, that is what another advantage, both permanent and stable so this is also one of the advantages.

No need to select backfill, so most of the time if there is a gravity retaining wall or a retaining wall, concrete retaining wall, then there is a condition generally to use the granular backfill because of many reason what we have already discussed in the soil mechanics foundation engineering and generally backfill is use granular materials should be free graining.

But here actually there is no need there is no backfill separately it is required because we are not backfilling, we are only inserting the anchor there, need to deep foundation support, there is no need, then fast construction that is also like nail this is also construction is fast but as we have mentioned that compared to anchor, nail is also faster actually that is advantage we have mentioned there, less surface right of way issue, right of way issue that means when there will be retaining wall construction right of way is

required, if it is a this type of wall, anchor wall is there right of way will be less, so that is what these are all several advantages and there are of course, some disadvantages.

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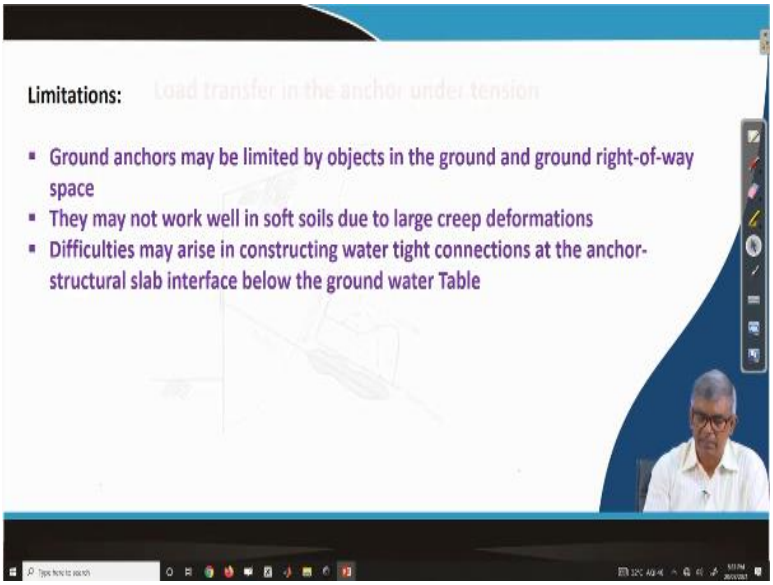


Limitations will be ground anchors may be limited by objects in the ground and ground right of way space and they may not work well in soft soil, that is obvious due to large creep deformation already mentioned that if there is a highly plastic soil organic soil because of this creep you need to take clear, but generally it should not be used, until and unless is very essential and if it is very essential to us then this can be used with a lot of care.

The difficulties may arise in constructing water tight connection at the anchor structural slab interface below the groundwater table. Below the groundwater table this construction is watertight construction is somewhat the little difficult. These are all minor limitation and otherwise advantages are many.

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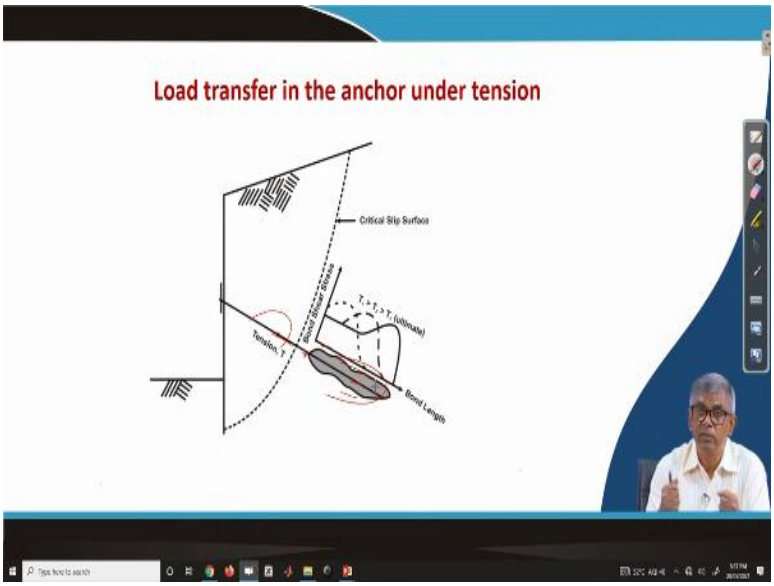


And load transfer in the anchor under tension. You can see here this is the one, this is the facing and this is the tendon and this is the anchor point. This entire thing will be in tension, this portion and under these what will be the load transfer mechanism in this zone, actually how it will be you can see here that when did if tension can vary because of many reason.

If the tension is $T_1$ and it become $T_1$ to $T_2$ and again from $T_2$ to $T_3$ and in the increasing that means $T_1$, $T_2$ is greater than $T_1$, $T_3$ is greater than, $T_1$ is greater than $T_2$, $T_2$ is greater than $T_3$ if this is the way and then you can see that different distribution of stresses will be like this, it will be constant almost here up to some distance and then it will be increasing to reaching to an axiom value and then it will be at this head anchor head it will become zero, so like this.

Almost similar they are actually from the failure surface to the end of and that is the actually were actually how to design how what is the length required, here actually you do not design the length, you have to fix some distance and accordingly you have to make, of course you have to give what is the distance required you have to design and so here actually, how it will be distributed from the starting from this up to these actually it is in tension of this portion is tension and beyond these what is not in tension, but this entire thing because of the resistance between the soil and this it will be holding that

tension and that tension actually when it will go from this and how it is varying it is given in this diagram or the sketch.

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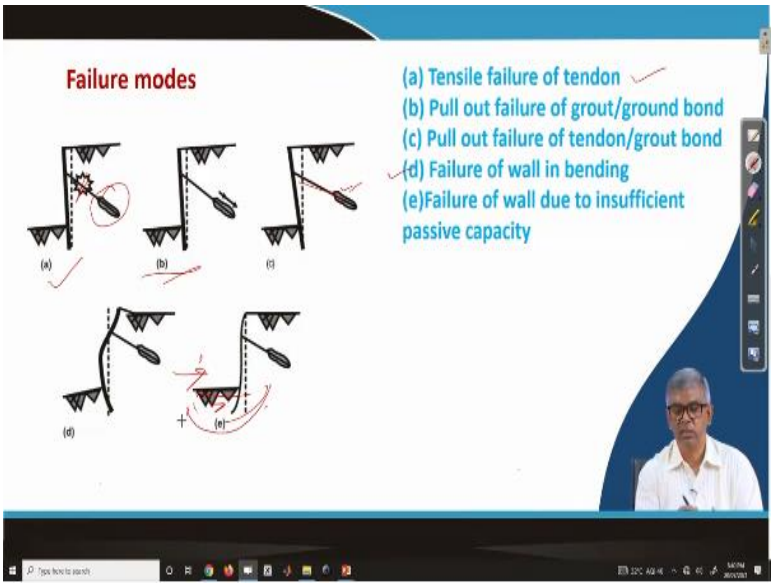


Now most important thing similar to the previous one, what the way we have discussed about the failure mechanism of nail, here also failure also different mechanism of failure will be there in the anchor also. You can see here there is an anchor failure, tensile failure of the tendon. In this portion actually tension is applied and the anchor, sufficient anchoring strength is developed but because of this excessive strength tension tendon may fail, that is called tensile failure of the tendon.

Then B actually the entire bond strength may not be enough, so because of the pullout failure of the grout ground bond. This grout and ground that is bond the anchor actually having bond between grout and the ground, that actually if there is insufficient then pull out will be pulled out of the anchor will happen, that is actually pull-out failure of ground grout bond and then pull-out failure of tendon ground.

Here actually the grout and ground maybe enough bond is there, it is holding in place, but because of this tension in the tendon that the inside also will have also tendency to have tension if it is insufficient, strong enough and but the bond strength between the steel and

the grout is not enough then it will be coming out from this, so that is actually called pullout failure of tendon ground grout bond failure.

And then this is actually, this one that is failure, this one will go D, so failure of wall in bending. Here you can see tendon also is quite good, is in excessive amount of force is applied and strong tendon is designed, strong ground anchor is designed but because of this excessive force, this force actually the anchor is trying to pull this side and this force also pushing this both together because of that wall may take this shape and this bending is it too much then it may have collapse.

That is actually failure of wall bending because of excessive bending it can fail and then is a failure of wall due to insufficient passive resistance. You can see there you are holding this wall or this side actually, the bottom has to have some resistance this from this side.

It is pulling this side and when it will be pulling this side it will have tendency to move this side, but if this side, this passive resistance is not enough then sometimes this anchor is there, tendon is there but soil will be moving in this direction, like this soil move this direction. This is actual failure of wall due to insufficient passive capacity.

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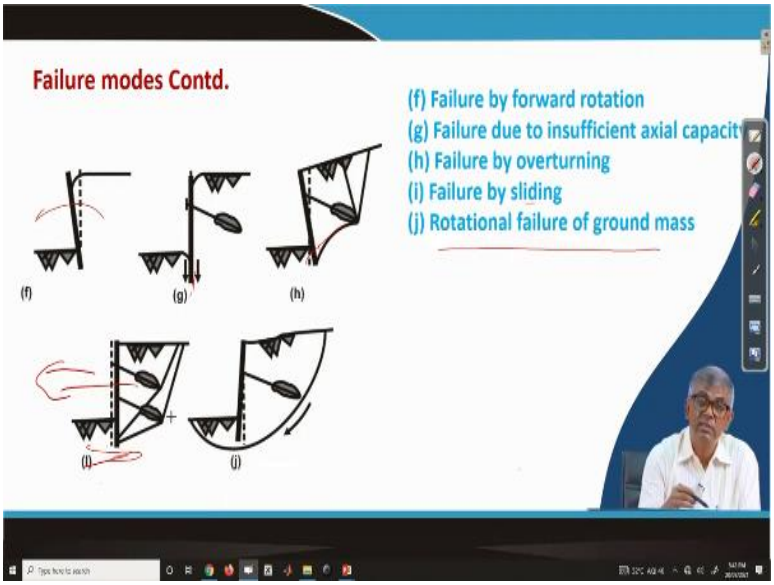

Some more are there let us go to the, let me go to the next slide. This is actually the one failure by forward rotation, you can see here the anchor is there, but still the wall may have movement in this direction and as a result the failure may happen and then the failure due to insufficient axial capacity, you can see everything is there the axial capacity is insufficient that can fail, then there is a failure by overturning, you see this, the wall is moving this direction and this anchor is like this, then the entire thing can overturn, entire this the up from here to here the center mass can overturn, so failure by overturning.

Then failure by sliding and see that anchor and all together this is a system is stable. But now the effect of these anchor soil mass is up to this the entire soil mass is given some amount of passive force and here actually if there is not enough passive resistance develop the entire thing may move in these directions horizontally that is actually failure by sliding even though the anchor is not failing, the tendon was not failing nothing is there but still the entire, the stabilized mass because of the insufficient development of frictional resistance at the base it may slide at this level.

And then rotational failure of the ground mass, you can see here it is stable grouted mass, but at some distance entire failure are globally, entire wall, anchor, and tendon together with some amount of soil at the foot and at the backfield together it may rotate and fail, and this is another type of failure. This is almost like global failure, this can also happen, so there are ten different ways of failure may occur in your anchors.

like this much actually and next actually will be designed aspect of anchors like nail we have discussed, based on certain aspects of nails soil wall we have developed some design methodology and finally you have shown some design chart how to use that design chart to design the nail spacing, nail diameter and all similar to that we have discussed right now, the various aspects of anchors.

And based on these aspects actually you can arrive at the design of the anchor system, that means, how much length a bond is required, how much bond strength is required, what is the tendon length is required, what is the tendon diameter, diameter of tendon is required what should be the, all those things actually finally can be done similar to the

nail and which may be taken in the next lecture with all details and then after completing that we can show some illustrative examples. With this I will close here today, thank you.